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(Selections from the Author's Summary)

COLLECTION OF THE MATERIAL FOR THE INVESTIGATION

Under the leadership and planning of the Forestry Research Institute's present director, professor Manfred Näslund, a production investigation on a broad basis was put in hand by the Institute's Department of Forestry in the year 1941. The main purpose of this investigation was to provide practical forestry workers with more definite direction for determining the magnitude of the production as regards its volume and value under the effects of different forms and degrees of thinning. As a first stage in this very comprehensive and exhaustive investigation a total of 981 temporary sample plots in undisturbed stands (intact stands insofar as thinning is concerned) were laid out in different parts of Sweden during the years 1941-1948.

The investigation was also arranged in such a way, however, as to allow the observation material collected to be employed for a series of special studies, including an investigation of the variation in the widths of the annual rings in pine and spruce due to climatic conditions. By boring a number of representative sample trees selected from each sample plot laid out, at breast height with the Pressler increment borer, a very large number of increment cores was collected from the sample plots in unthinned stands.

MEASUREMENT OF THE ANNUAL RING MATERIAL

During the field work each separate increment core was placed in a cardboard tube provided for the purpose, on which the necessary registration data for the subsequent identification of the increment core were noted. The increment cores were then dispatched to the Forestry Research Institute where they were stored in a special archives section while awaiting measurement. Immediately before starting the latter the cores were soaked for about one hour, this time being necessary to compensate for the changes in length caused by shrinkage after the increment core had been removed from the living tree. (Eklund 1951). The measurements were then carried out in special recording machines (Eklund 1949) . . . from the year of boring back to 1900.

The mean annual ring-widths for different calendar years were then plotted as points surrounded by circles on a diagram printed in the form of special chart paper. . . The graphic picture of the annual ring development thus obtained has permitted the close checking and sifting of the annual ring material, in which sample plots were excluded which, according to the annual ring diagram, exhibited signs of an abnormal or disturbed annual ring development.

The elimination of the age-decrease for annual ring series either representing separate sample plots or groups of sample plots can be effected by regressive analytical means in accordance with a method originally proposed by Näslund (1942). Briefly, this consists in reproducing the declining tendency of the age-decrease by a function . . . the constants for which are obtained by numerical adjustment of the annual ring series according to the method of least squares, after which the observed mean annual ring widths for each of the calendar years included in the investigation are placed in relation with that calculated according to the function, whereupon a so-called annual ring index is obtained. This is independent of the absolute size of the annual ring-widths and constitutes an approximate expression for the calendar year's property as a good or bad growing year with respect to the increase in diameter. An index value of 100 represents a normal year, whereas an index figure of 120, for example, indicates that the annual ring width is 20% greater than the normal.

When an annual ring series is adjusted numerically in accordance with a certain type of function which will thus reproduce the age-decrease of the annual ring-width schematically, and the annual ring variations are then converted to an annual ring index, any influence of a long-period climatic fluctuation is eliminated. The advance made during the past few decades in climatology, meteorology, glacierology, and other branches of scientific research have unanimously proved that the general climatic situation has undergone demonstrable changes over large parts of the earth's surface since the beginning of the present century. As a working hypothesis, therefore, it is necessary to reckon with the probability that the climatic fluctuations in our latitudes have left their record on the annual rings of our forest trees.

MAIN OUTLINE OF THE MATHEMATICAL-STATISTICAL TREATMENT

The treatment of the comprehensive observation material has been primarily directed to the derivation of functions which reproduce the collective effect which

the observation year's-, date-, and age groups exercise on the width of the annual rings. The term "observation year's group" refers to the groups resulting after dividing the annual ring material into groups of five years beginning from the year 1900. . . The date group, on the other hand, refers to the point of time at which the trees examined, in accordance with the age determination undertaken at the same time as the annual ring measurement, were found to have reached breast height. . .

The regression coefficient which represents an expression for the variation in the annual ring-widths due to climatic conditions for the five-year observation year groups has been converted graphically to an annual ring index for each separate calendar year over the period 1900-1945. This annual ring index may be considered to reflect the variations in the annual ring-widths due to climatic conditions for pine and spruce in northern Sweden fairly satisfactorily.

ANNUAL RING INDEX-SERIES

Pine. . . . The pine annual ring index follows a relatively pronounced undulating course. Specially characteristic in this respect are the series of high index values which occurred at the beginning of the 1920's and indicate that the climate exercised a very noticeable favorable effect on the annual ring formation of pines. The pine index-series thus shows that this takes place under a marked influence of the secondary climatic effects from the immediately preceding period of vegetation, and probably foremost amongst them, the changes in the size of the assimilating foliage which is a consequence of the climatic conditions existing at the time. . . A constellation of climatic conditions leads at times to an ample blooming and cone yield in which connection appreciable quantities of assimilated material are probably absorbed at the cost of the annual ring formation. Similarly, it is probable that the annual ring formation is impaired by pronounced attacks of insects that consume the foliage of the crown or destroy it in other ways. The effects are probably the same where a malignant attack of foliage-destructive fungi occurs.

The annual ring index-series for pine in the north of Sweden has been compared with annual ring index-series for the north, south, and whole of Finland. Correlation calculations made in conjunction with graphic comparisons have thereby shown that, under the weather conditions prevailing during the period of comparison 1900-1936 and different calendar years, a relatively similar influence on the annual ring formation of pine has been noted in a number of cases in northern Sweden and in the different parts of Finland.

Spruce . . . The undulatory nature of the annual ring index-series so characteristic for pine is not found in the index-series for spruce. The latter exhibits appreciable similarities and considerable correlation with a previous index-series for spruce in northern Sweden drawn up by Näslund (1942). Comparisons with the Finnish index-series give a higher correlation between the annual ring variations of pine than those of spruce, so that within a wide geographical area the growth climate in different calendar years is probably recorded in a more uniform manner in the annual rings of pi an those of spruce.

THE ANNUAL RING INDEX OF PINE COMPARED WITH THAT OF SPRUCE

The relatively pronounced differences encountered in a comparison of the annual ring index-series of pine and spruce may be attributed to some extent to the fact that the annual ring formation of pine takes place under the strong influence of the radial growth during the preceding calendar year, whereas that of spruce is very slightly affected. . .

If the influence of auto-correlation on the annual ring formation of pine is eliminated, the annual ring index-series will undergo a very remarkable change. . . The very conspicuous undulation that marks the primary annual ring index-series is appreciably damped. A comparison with the "adjusted" annual ring index-series for spruce, which is practically identical with the primary series, leads to the astonishing result that the two adjusted index-series agree with each other in a very striking manner, particularly within certain sections of the time scale. . .

Since the annual ring formation in pine takes place to a considerable extent under the influence of secondary climatic effects from the immediately preceding vegetation periods, whereas spruce is not influenced at all, it is an obvious step to regard this as a manifestation of the differences which exist according to the foregoing, with respect to the rate of change of the assimilating masses of foliage in pine and spruce. In view of the fact that in northern Sweden the pine normally has 3-5 generations of needles living simultaneously, against 8-9 for spruce, and the growth of new foliage takes place under the influence of the weather during the vegetation period when needle buds are developed, the effect of weather favorable to growth over a few successive years leads to a far more rapid increase in the assimilating foliage of pine than in that of spruce.

CONE YIELD AND ANNUAL RING FORMATION

. . . Whereas the annual ring variations of spruce are chiefly affected by the weather conditions during the actual vegetation period but also undergo a perceptible influence due to the cone yield during this period, the annual ring variations in pine are primarily due to the weather conditions both during the actual vegetation period concerned and the immediately preceding periods. On the other hand, in this species of tree the cone yield does not as a rule appear to react on the annual ring variations to any great extent. The insufficient reliability of the observation material respecting the magnitude of the cone harvest for different years calls for certain caution in drawing conclusions in the foregoing connection, however.

THE ANNUAL RING INDEX-SERIES FOR DIFFERENT GEOGRAPHICAL AREAS

Provinces . . . The harsher the climatic conditions under which the annual ring formation takes place, the more strongly accentuated will be the character of the more prominent extreme years recorded, either as good or bad growing years. The annual ring index correlation likewise tends to increase the more northerly the position of the province in question is.

Climatic areas. From a comparison of the annual ring index-series for the areas in northern Sweden distinguished by Ångstrom as local continental and local maritime, it would appear that the climate has affected the annual ring variations in all areas in a relatively uniform manner. Nevertheless, certain differences between the various series indicate that these are specially marked to some extent. The conditions are the same for the annual index-series for the most northerly local climatic and local maritime areas on the one hand, and the other climatic areas on the other, which must be interpreted as a result of the somewhat strongly marked climatic conditions prevailing in the two first-mentioned areas.

Latitude groups. The climate must be considered to have exercised a slightly varying quantitative effect on the annual ring formation in different latitude groups. A very remarkable feature is found in the fact that the auto-correlation in the annual ring index-series for pine tends to increase with the higher degrees of latitude. The farther north one goes, the more markedly the annual ring formation of pine appear to be dependent upon the weather conditions during the period in which the immediately preceding annual ring is formed.

Similarly to pine, the annual ring index-series for spruce changes somewhat in character the farther north the series represented by the latitude group is located. For spruce also the auto-correlation tends to increase somewhat at higher latitudes. In this instance, however, the tendency is not so pronounced or statistically reliable as in the case of pine. . .

Altitudes. On dividing the annual ring material according to the four following altitudes: <200, 200—299, 300—399 and >400 m above sea level it is found that the annual ring variations run relatively synchronously, although a certain variable quantitative effect makes its appearance in the annual ring formation. No tendency towards an increase in auto-correlation with changes in the altitude above sea level is noticeable either in the case of pine or spruce.

Site classes. Taking the age and average height of the stand as a starting point, the annual ring material has been divided into five site classes. The annual ring index-series have then been worked out for each of these site classes. Comparisons between the annual ring-index series for these classes have shown that the variation in the annual ring-width due to climatic conditions takes place relatively independently of the stand's site class, both for pine and spruce. It should be emphasized here that this statement refers exclusively to the variations in the annual ring-widths due to climatic conditions and not to the absolute annual ring-width which is, of course, dependent to a great extent upon the site class.

Degrees of density. . . . "a stand is considered to be dense when the crowns of the separate trees interlace with one another or touch one another so that the ground is in shadow at all points". Comparisons between the annual ring index-series for the different degrees of density have shown that the density does not exercise any actual influence on the variation of the annual ring-width due to climatic conditions on pine or spruce.

Degrees of moisture. . . . The apparently slight influence of the water factor on the annual ring-width variation due to climatic conditions supports the view advanced earlier that in northern Sweden it is primarily the temperature conditions during the vegetation period, and probably during the most intensive phase of the latter, that cause the annual variations in the annual ring-widths of spruce. On the other hand, in the case of pine it is necessary to reckon with the fact that the temperature conditions not only exercise an influence during the actual vegetation period but that they are also dependent to a certain extent upon secondary climatic effects which in their turn are associated with the weather conditions during the immediately preceding vegetation period.

THE PRESENT-DAY CLIMATIC FLUCTUATION AND THE ANNUAL RINGS OF FOREST TREES

When studying the relatively comprehensive annual ring material included in the present investigation a special endeavor was made to determine and reproduce numerically any possible long-period influence of the climate on the annual ring index-series of pine and spruce. It was not possible, however, to obtain any reliable and definite criteria relating to the recording of such influence on the annual rings of the tree species in question. The temperature conditions remained substantially unchanged for an appreciable time during the actual vegetation period. The progressive changes in the climatic situation are primarily due to a rise in the winter temperature but are not the result of a general rise of temperature over the individual years, being caused by the fact that the extremely cold winters have occurred less frequently. In all probability the mathematical-statistical methods at present available are not sufficiently developed to enable us to isolate successfully any long-period climatic effect from the complex of site and stand influences recorded in the annual rings of conifers.

THE PRACTICAL APPLICATION OF CLIMATIC CORRECTIONS AT THE PRESENT STAGE AND WITH A VIEW TO THE FUTURE

. . . In our latitudes the radial growth of both pine and spruce is characterized by such a marked variation due to climatic conditions that it must be taken into account in forestry calculations which have for their purpose the accurate determination of the thickness increment of individual trees, stands, or entire forests. In this connection it is extremely important that the increment noted should be critically examined against the background of the climate's influence on growth over the period covered by the calculation. . .

. . . In obtaining data for climatic corrections of the increment in the future there is reason to place certain hopes on a comparison between the increment assessment prepared annually by our National Forest Survey for different regions of the country. It is possible that in order to obtain reliable annual ring indexes both for research work and for practical forestry we may find it necessary to prepare and carry on a continuous investigation of the annual ring development in specially selected undisturbed stands which are known as "indicator stands". Another possible method of procedure would be to derive so-called climatic functions, in accordance with which the magnitude of the climatic corrections could be calculated on the basis of the "official" weather observations. . .

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